

Flow and Harmful Algal Blooms: Lessons Learned from Golden Algae



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Support:

Texas Parks & Wildlife Department, US Department of Energy, US Army Corps of Engineers

Whole Lake Observations

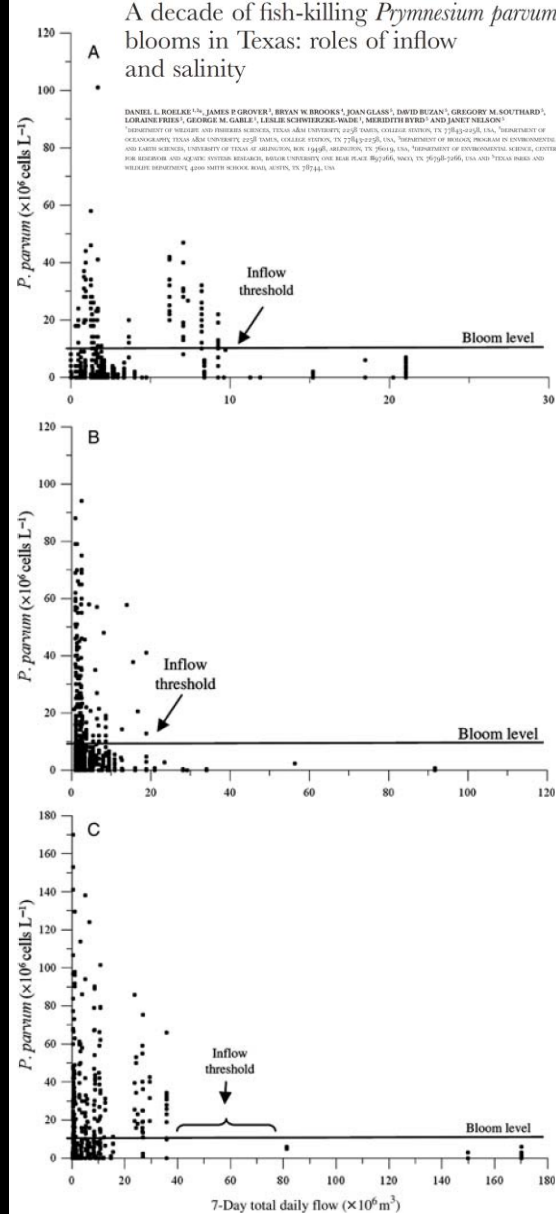
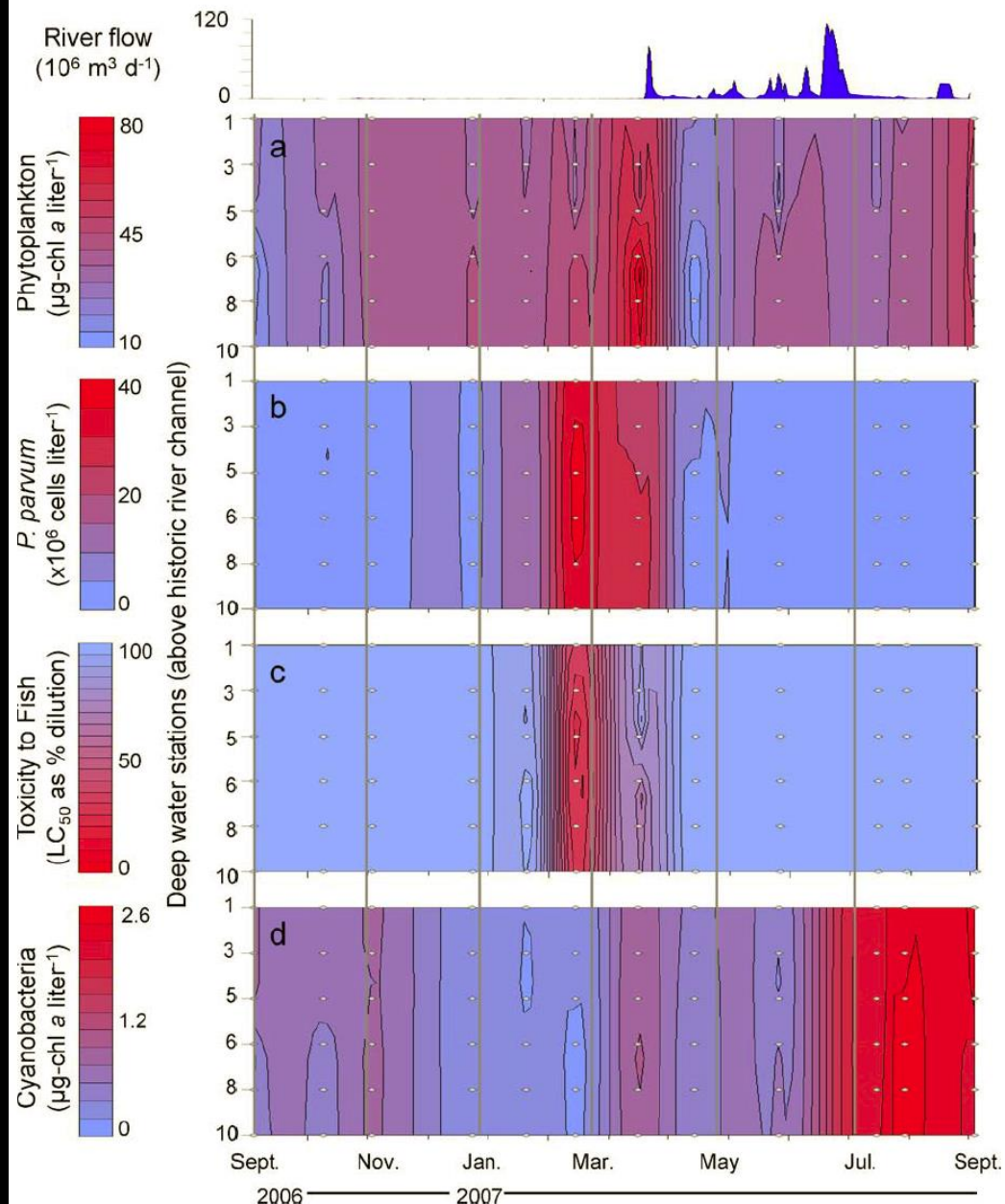
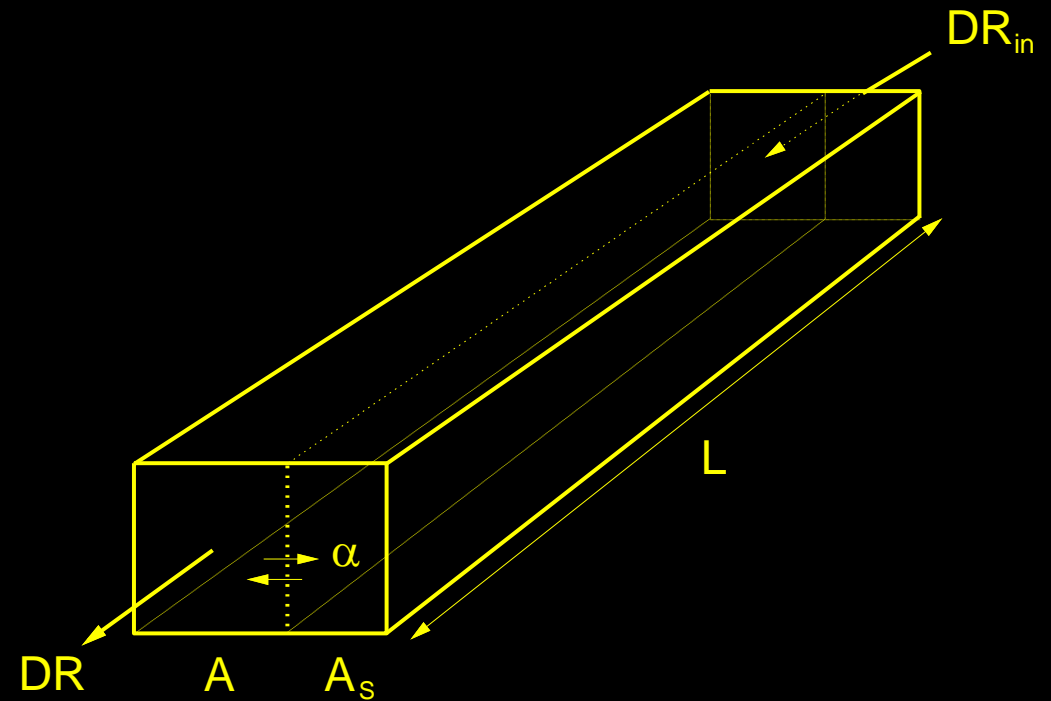


Fig. 5. *Prymnesium parvum* population density plotted against the cumulative inflow over the 7-day period prior to the date of sampling for Lakes Possum Kingdom (A), Granbury (B) and Whitney (C). Population densities greater than 10×10^6 cells L^{-1} , the defined bloom level, occurred when 7-day accumulated inflows were $<10 \times 10^6$ m^3 for Lake Possum Kingdom, $<20 \times 10^6$ m^3 for Lake Granbury and conservatively $<40 \times 10^6$ m^3 for Lake Whitney. These bloom-inflow-thresholds corresponded to system flushing rates of 0.01, 0.12 and 0.10 day^{-1} .



One-dimensional continuum model of a riverine reservoir with a hydraulic storage zone



One-dimensional continuum model – governing equations

Main channel:

$$\frac{\partial N}{\partial t} = -DL \frac{\partial N}{\partial x} + \delta \frac{\partial^2 N}{\partial x^2} + \alpha (N_s - N) + rxns$$

$$\frac{\partial R}{\partial t} = -DL \frac{\partial R}{\partial x} + \delta \frac{\partial^2 R}{\partial x^2} + \alpha (R_s - R) + rxns$$

$$\frac{\partial C}{\partial t} = -DL \frac{\partial C}{\partial x} + \delta \frac{\partial^2 C}{\partial x^2} + \alpha (C_s - C) + rxns$$

Storage zone:

$$\frac{\partial N_s}{\partial t} = -\alpha \frac{A}{A_s} (N_s - N) + rxns$$

$$\frac{\partial R_s}{\partial t} = -\alpha \frac{A}{A_s} (R_s - R) + rxns$$

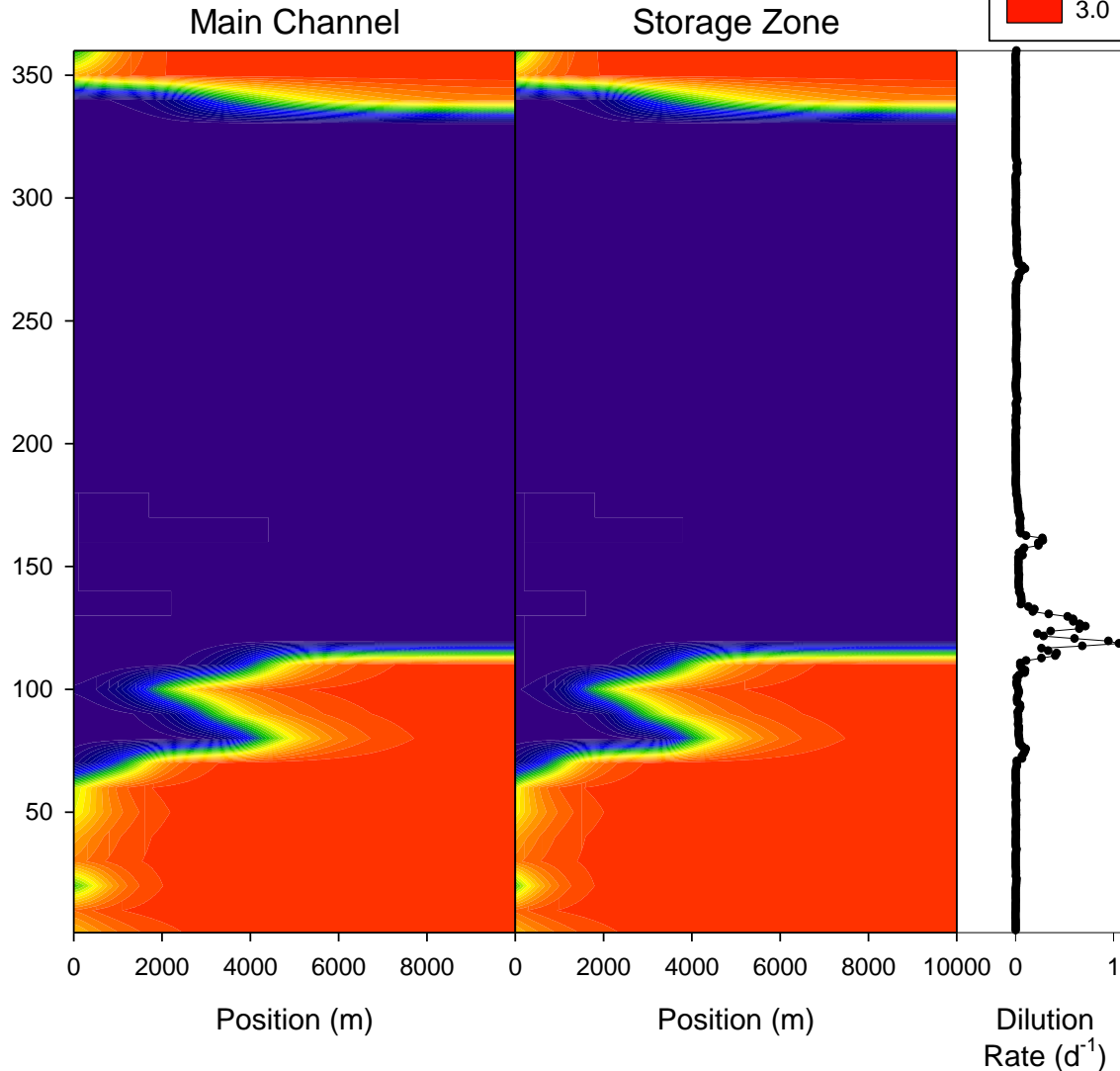
$$\frac{\partial C_s}{\partial t} = -\alpha \frac{A}{A_s} (C_s - C) + rxns$$

Advection velocity = DL

Dispersion (δ) = constant and high (wind driven)
or proportional to D (flow-driven)

P-limited Flagellates
Toxin ($\mu\text{g} / \text{liter}$)

Day of the Year



Flushing events during “wet” years can exceed critical flows to wash out blooms.

This run used constant, high δ (“wind driven”).

Results similar for “flow-driven” δ .

This run used constant temperature

Results similar for temperature-dependent reaction kinetics.

Can artificial flows mitigate blooms?

In situ mesocosm experiments...



Flushing levels (d^{-1})

- 0.05, 0.10 and 0.30
- once per week (T0, T7, T14)
- use deep, algae-free water from main stem of reservoir

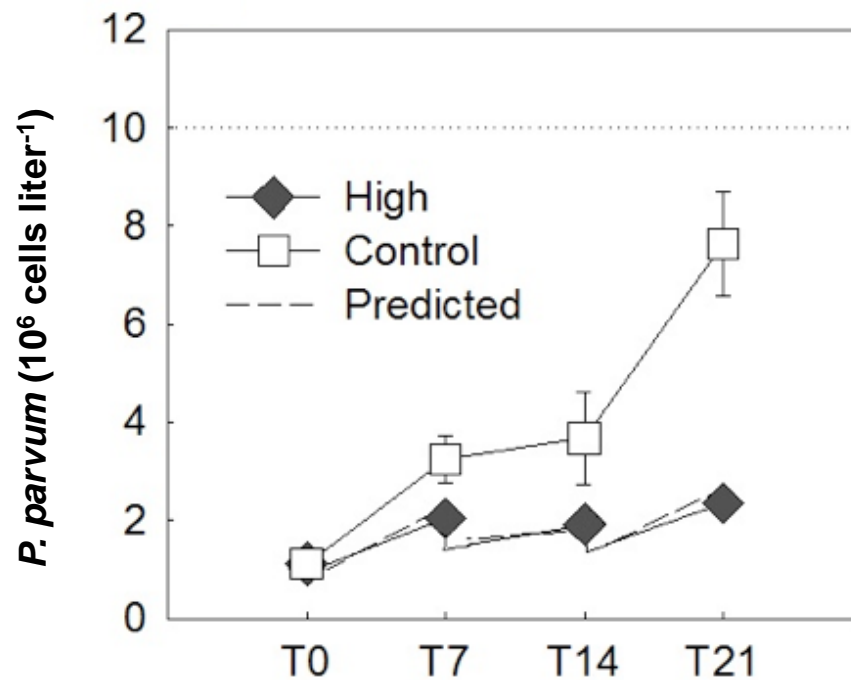
Captured periods of:

- pre-bloom
- bloom development

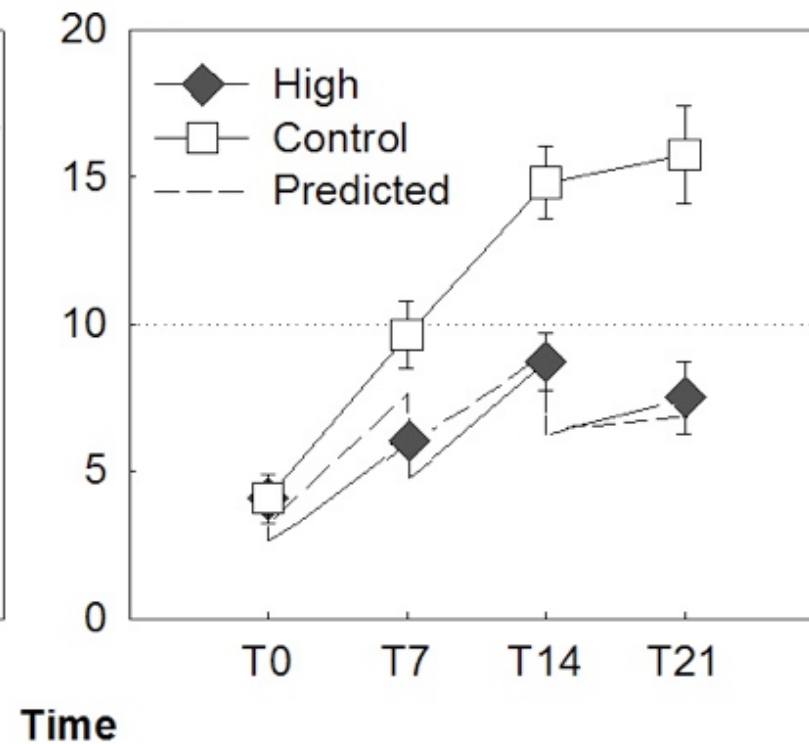
Spring 2010 experiments - Lake Granbury



Pre-bloom



Bloom development

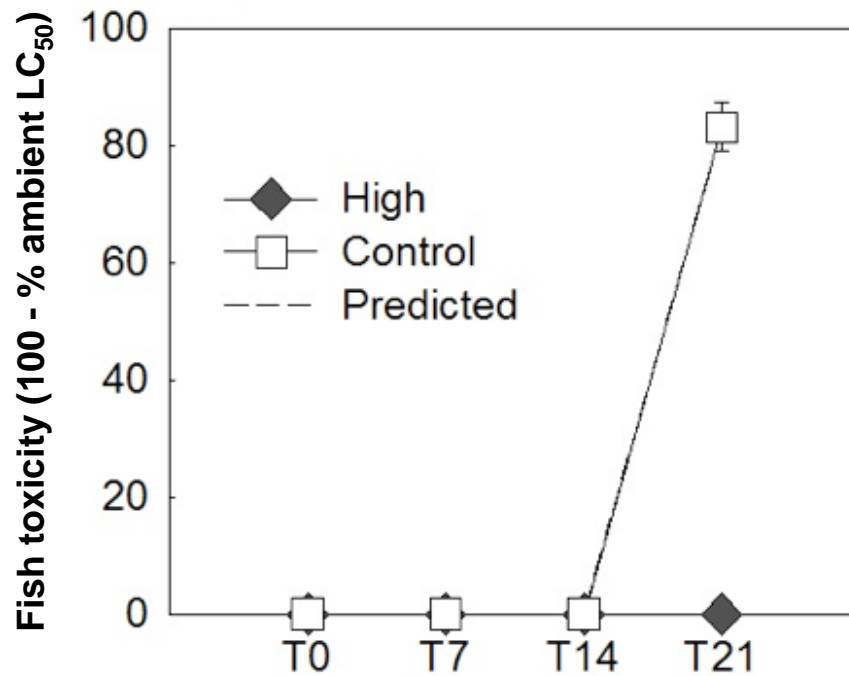


Flushing = 0.3 d⁻¹, once per week

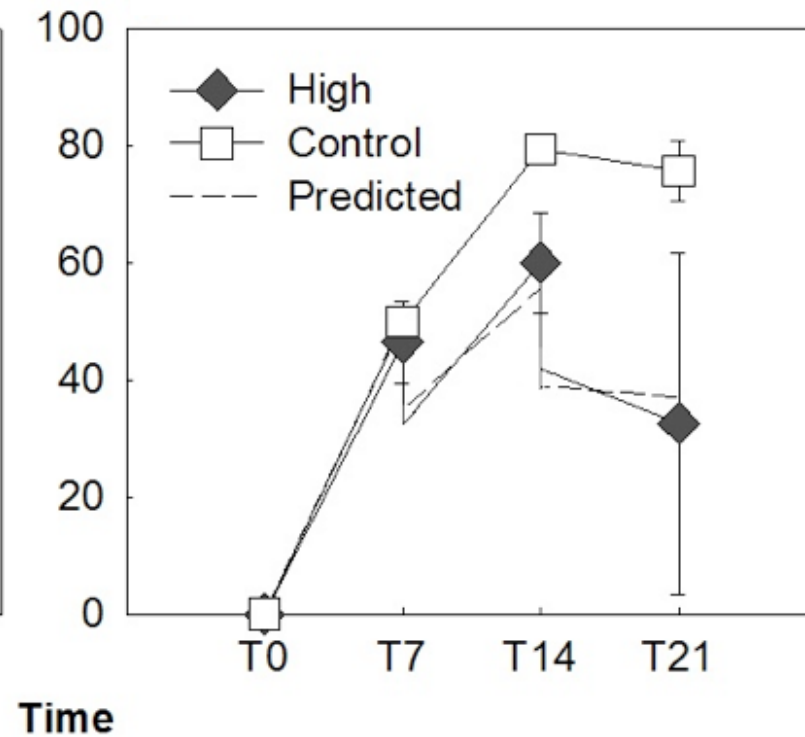


Spring 2010 experiments - Lake Granbury

Pre-bloom



Bloom development



Flushing = 0.3 d^{-1} , once per week

Scaling up for Lake Granbury

Pulse magnitude lasting one day
(one pulse per week
for two months, 8 events)

1-6 km patchiness

- 0.05 - 0.3 d⁻¹ equivalent to:

Coves of lakes

- 0.05 - 0.3 d⁻¹ equivalent to:

x10 ⁶ m ³ d ⁻¹	cfs	mgd
0.19 – 1.11	77 - 454	50 - 293
0.0075 – 0.045	3 - 18	2 - 12

Winter/Spring 2012 tracer experiments - Lake Granbury

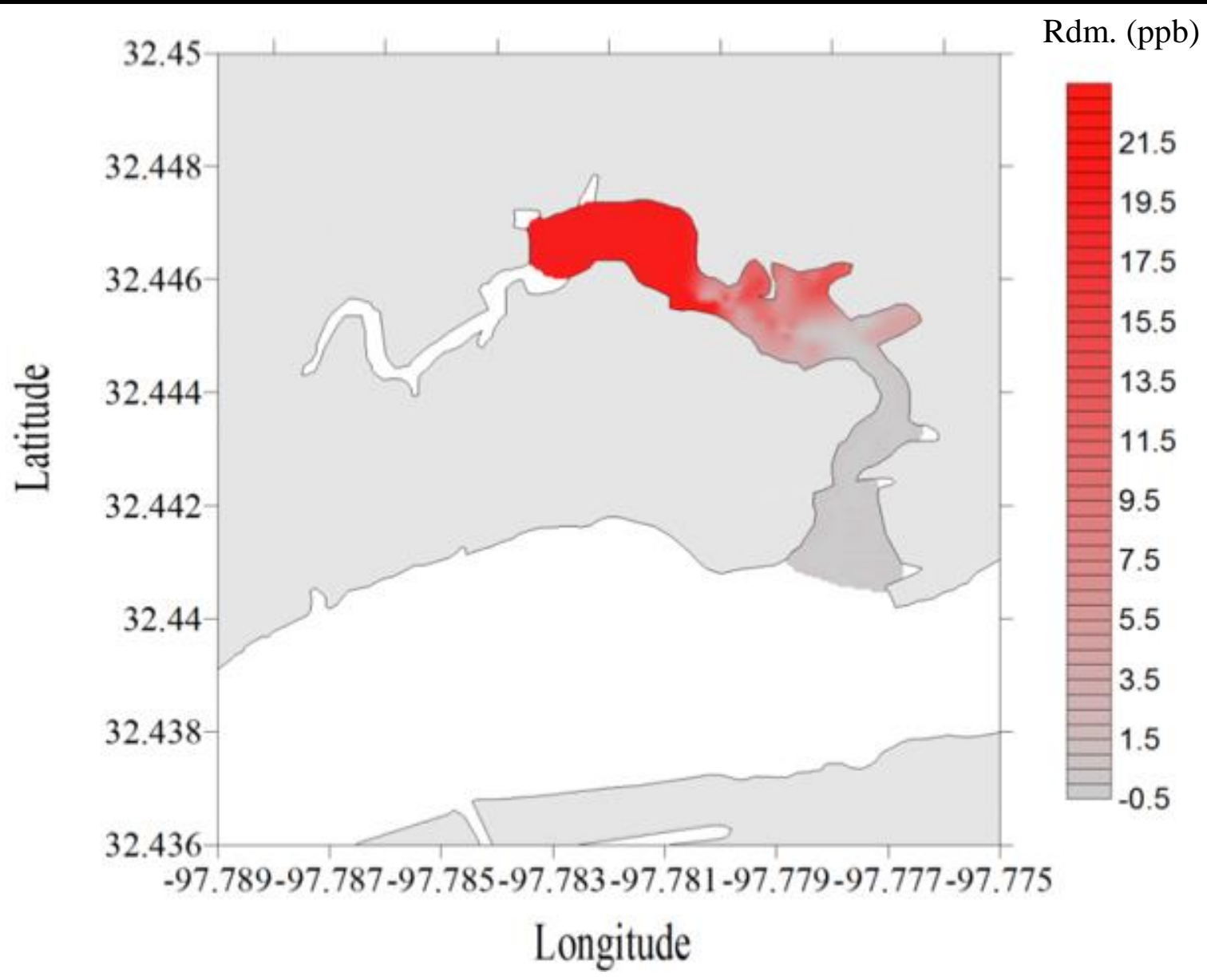


Add and track dye to determine exchange rate between cove and main lake (works against imposed flow)



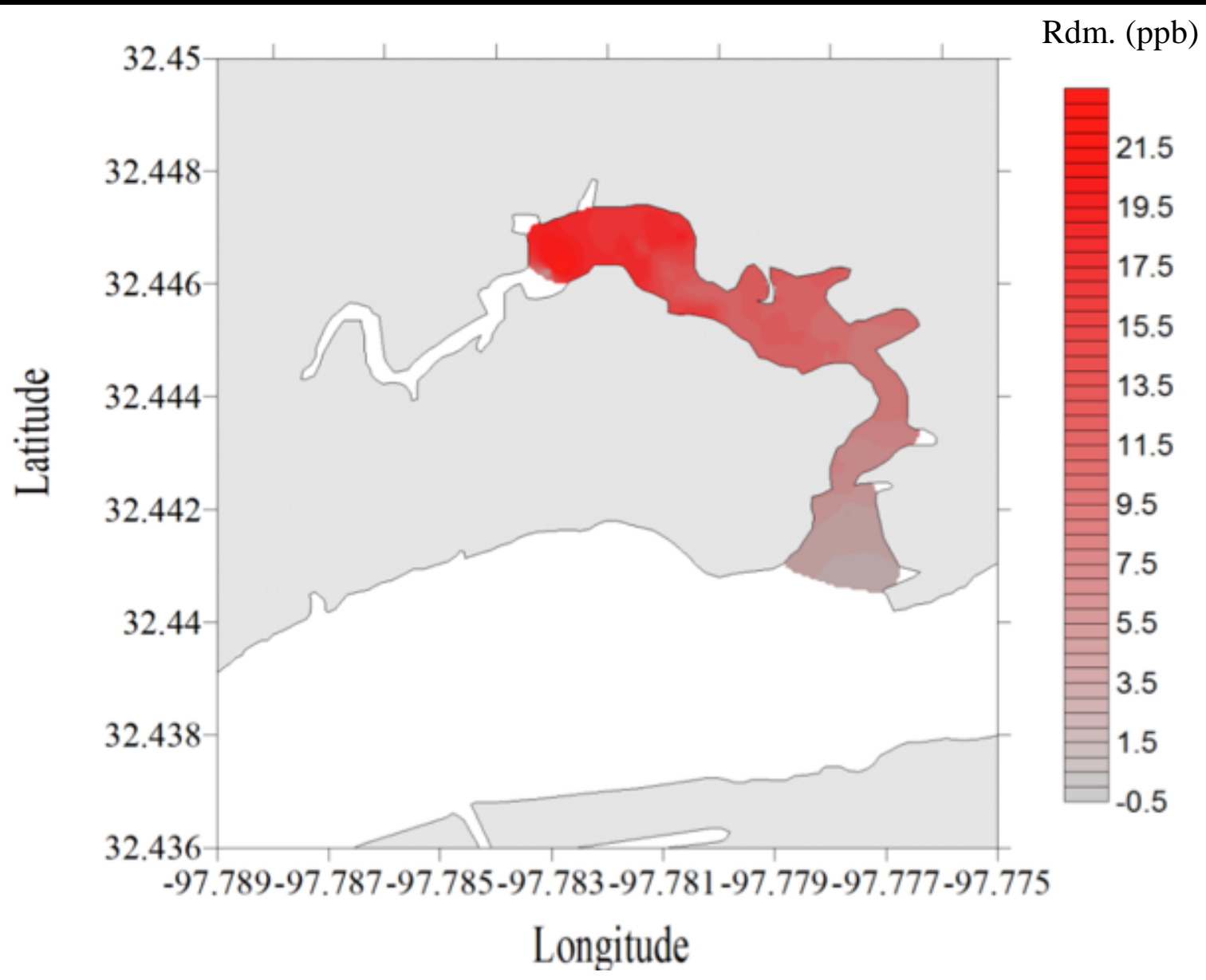
Winter/Spring 2012 tracer experiments - Lake Granbury

Ranger's Slough
Day 1



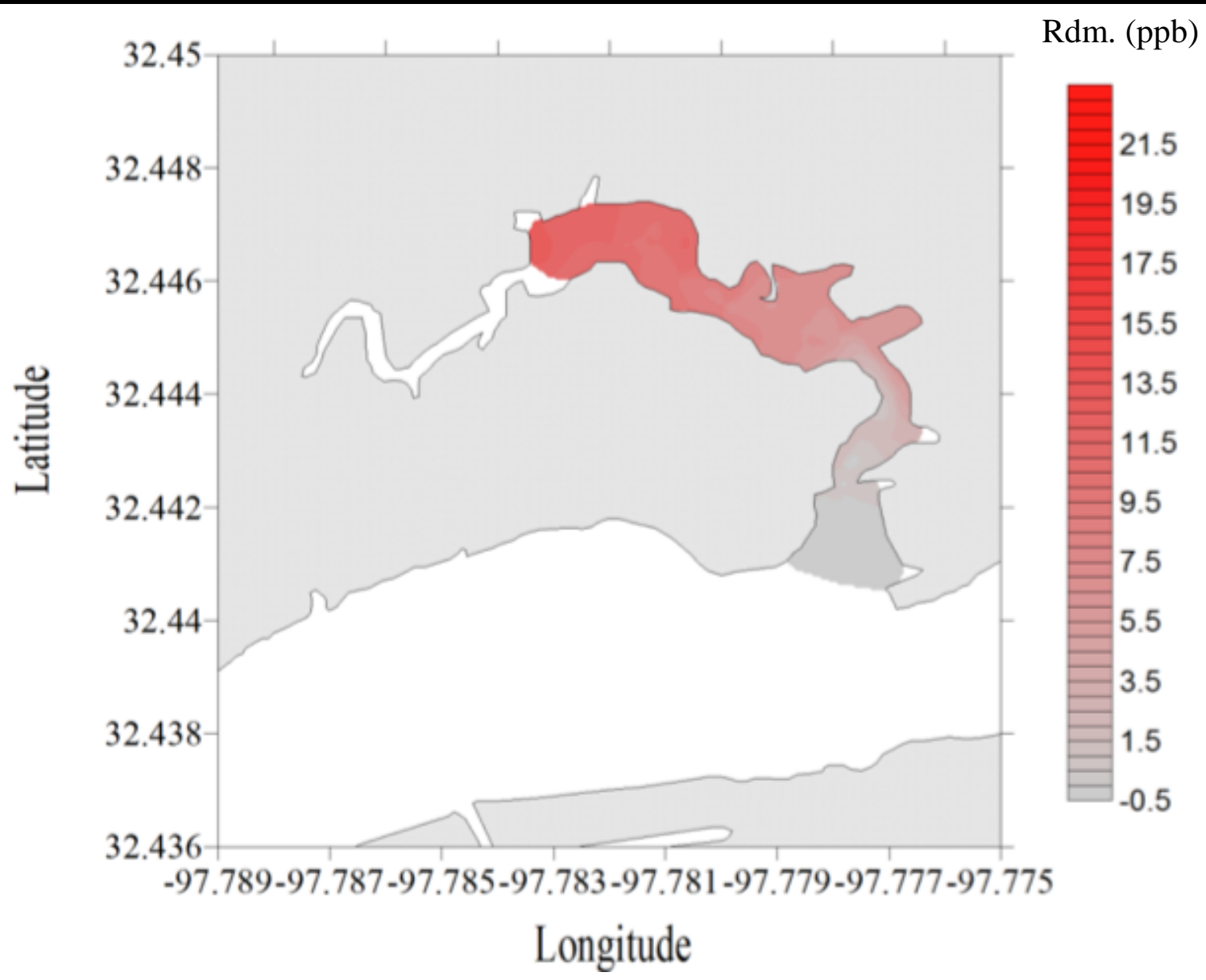
Winter/Spring 2012 tracer experiments - Lake Granbury

Ranger's Slough
Day 2



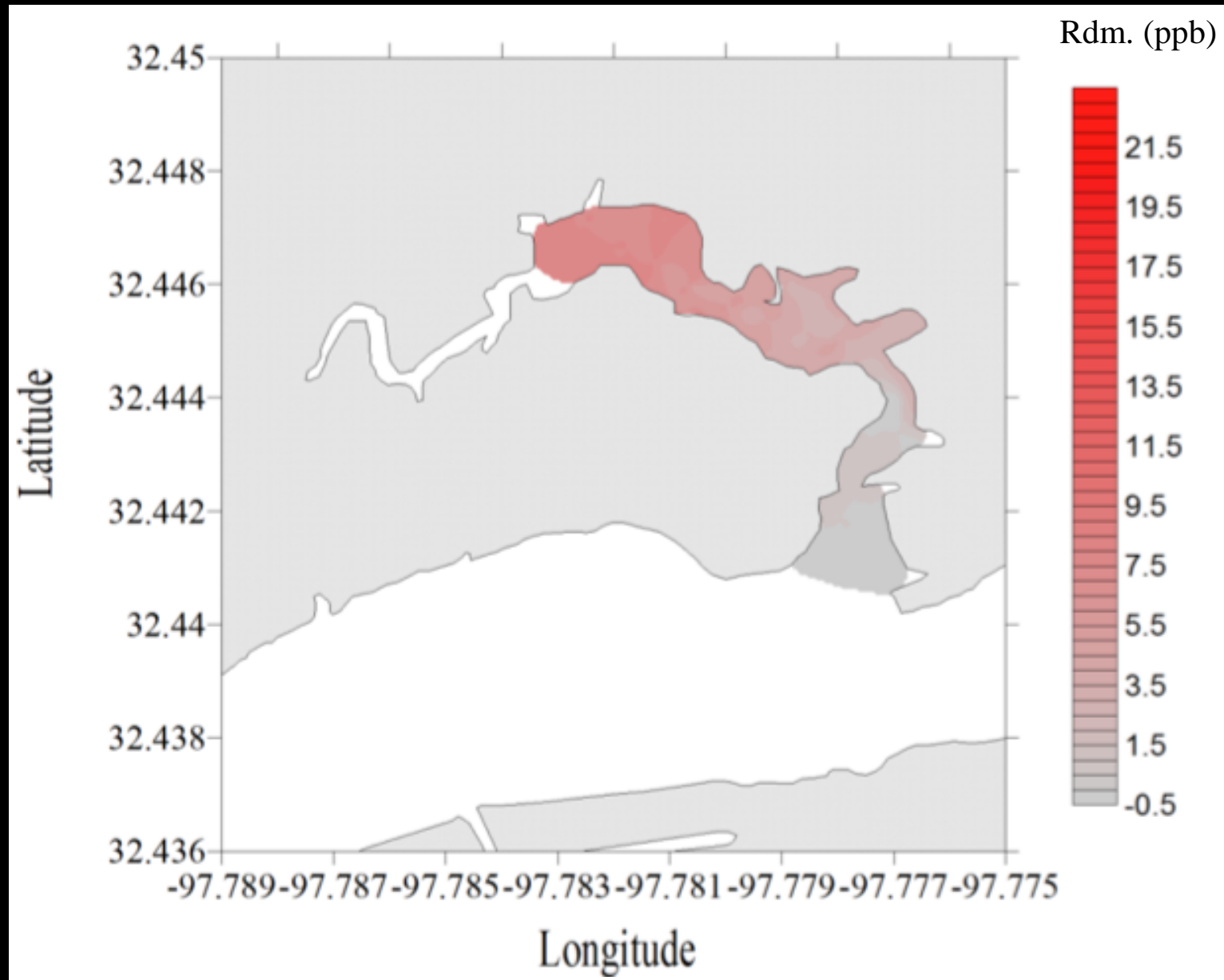
Winter/Spring 2012 tracer experiments - Lake Granbury

Ranger's Slough
Day 3



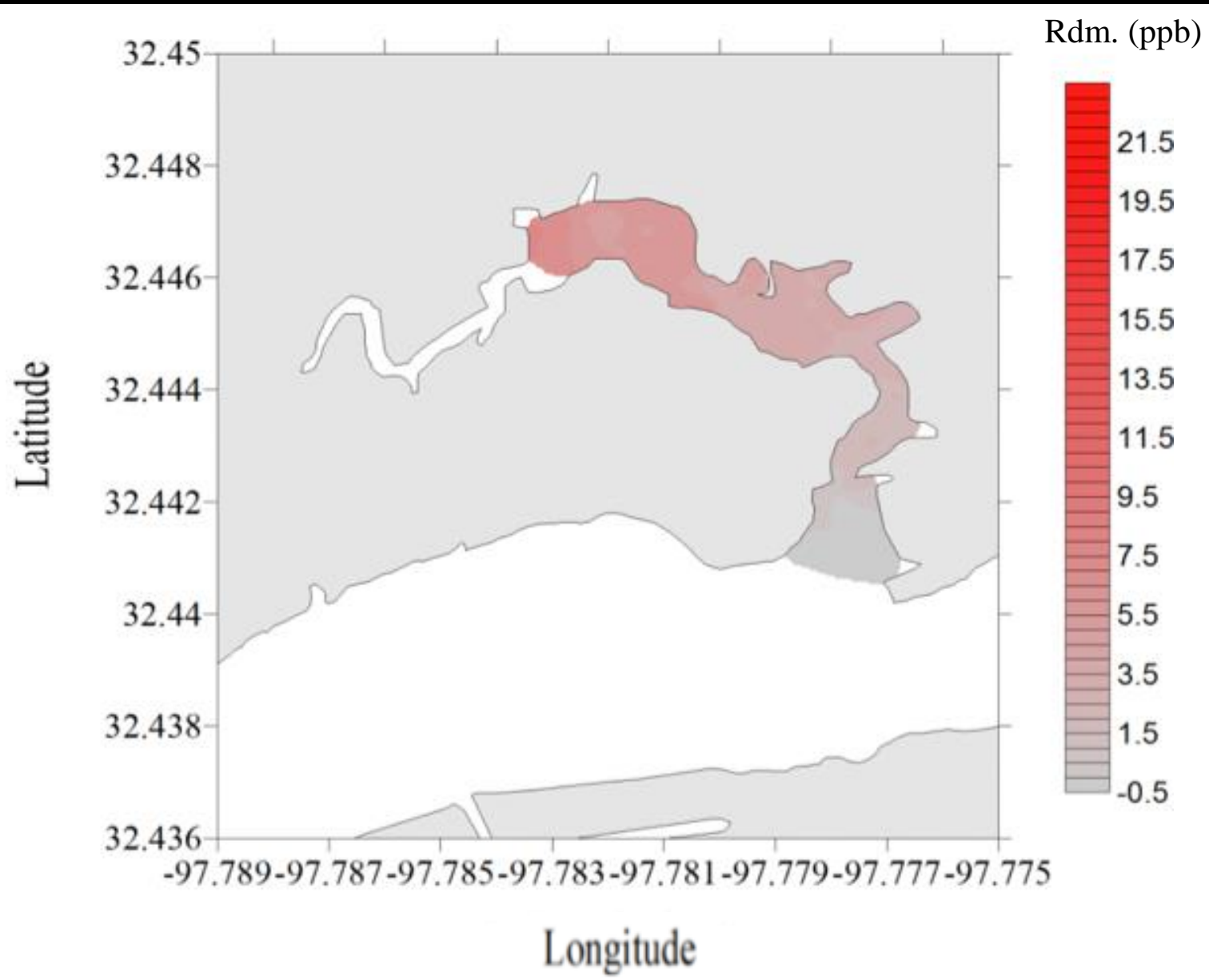
Winter/Spring 2012 tracer experiments - Lake Granbury

Ranger's Slough
Day 4



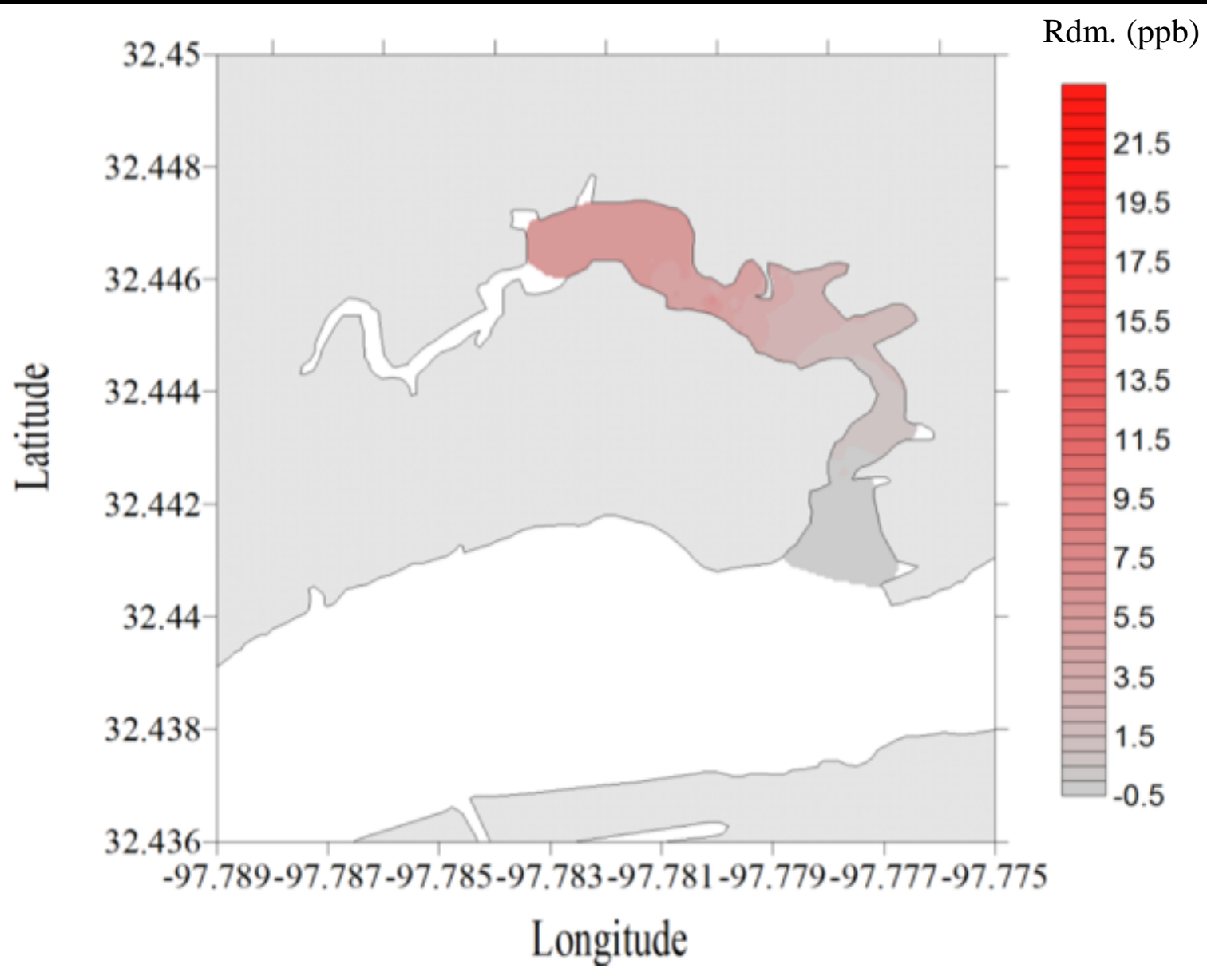
Winter/Spring 2012 tracer experiments - Lake Granbury

Ranger's Slough
Day 5

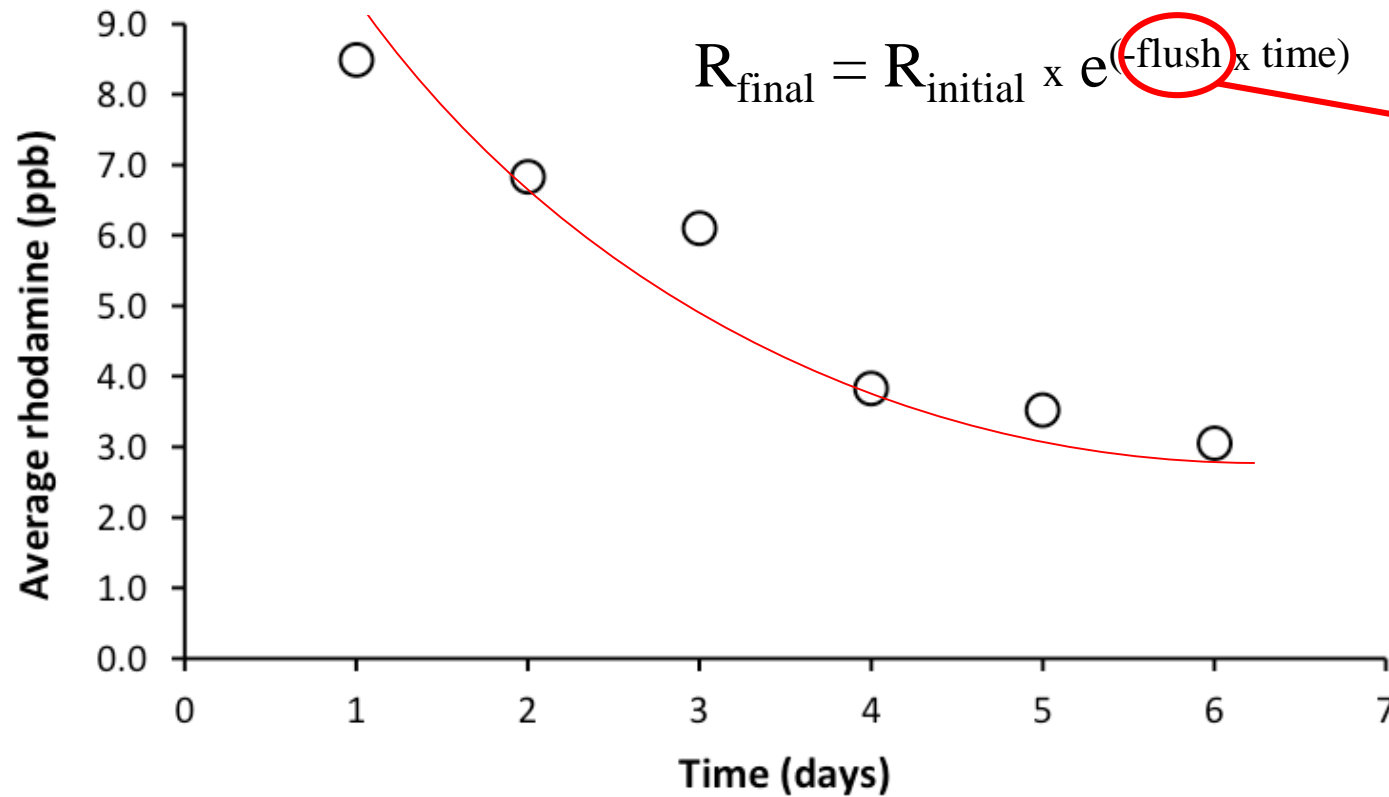


Winter/Spring 2012 tracer experiments - Lake Granbury

Ranger's Slough
Day 6



Winter/Spring 2012 tracer experiments - Lake Granbury

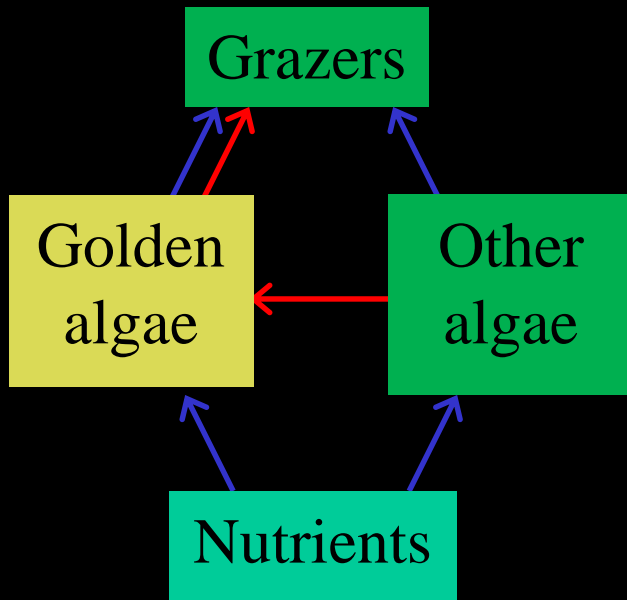


Ranger's Slough

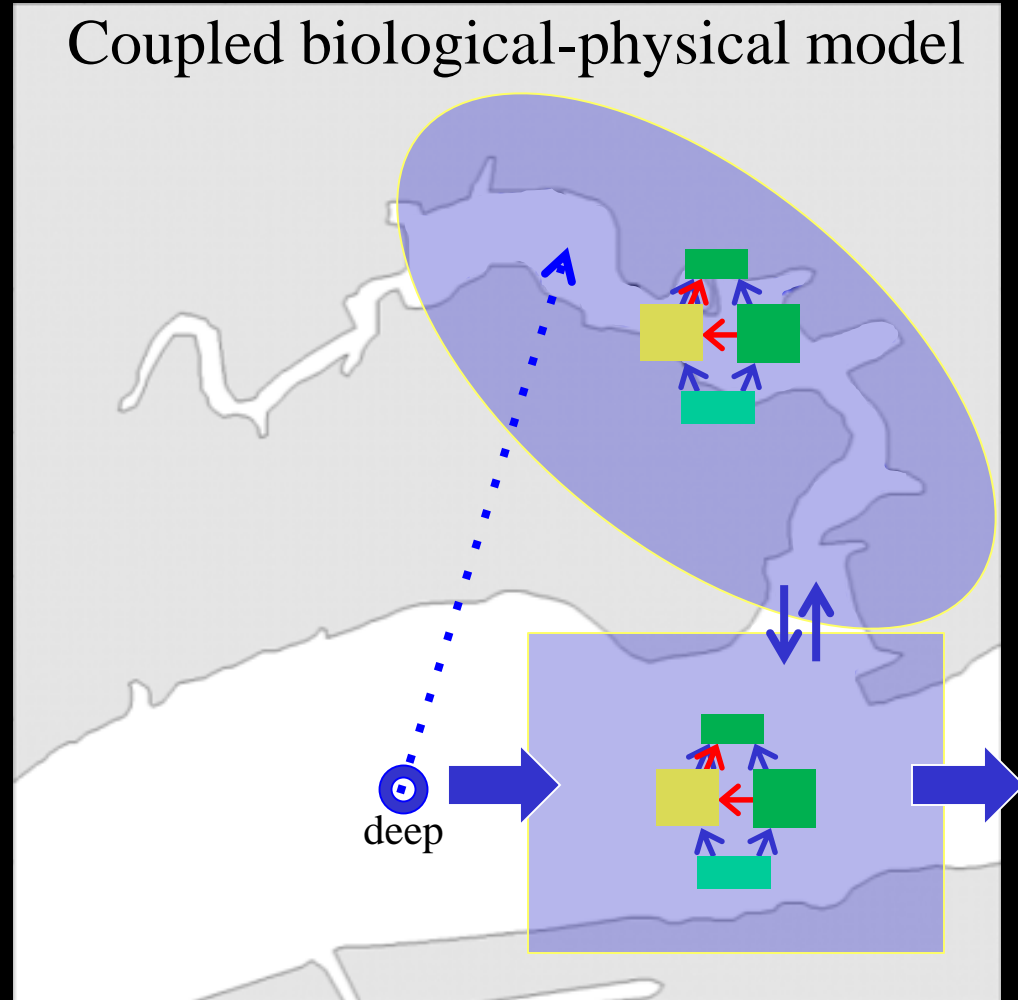
Flush =
0.15 to 0.25 d⁻¹

Mathematical modeling of managed deep-water flushing

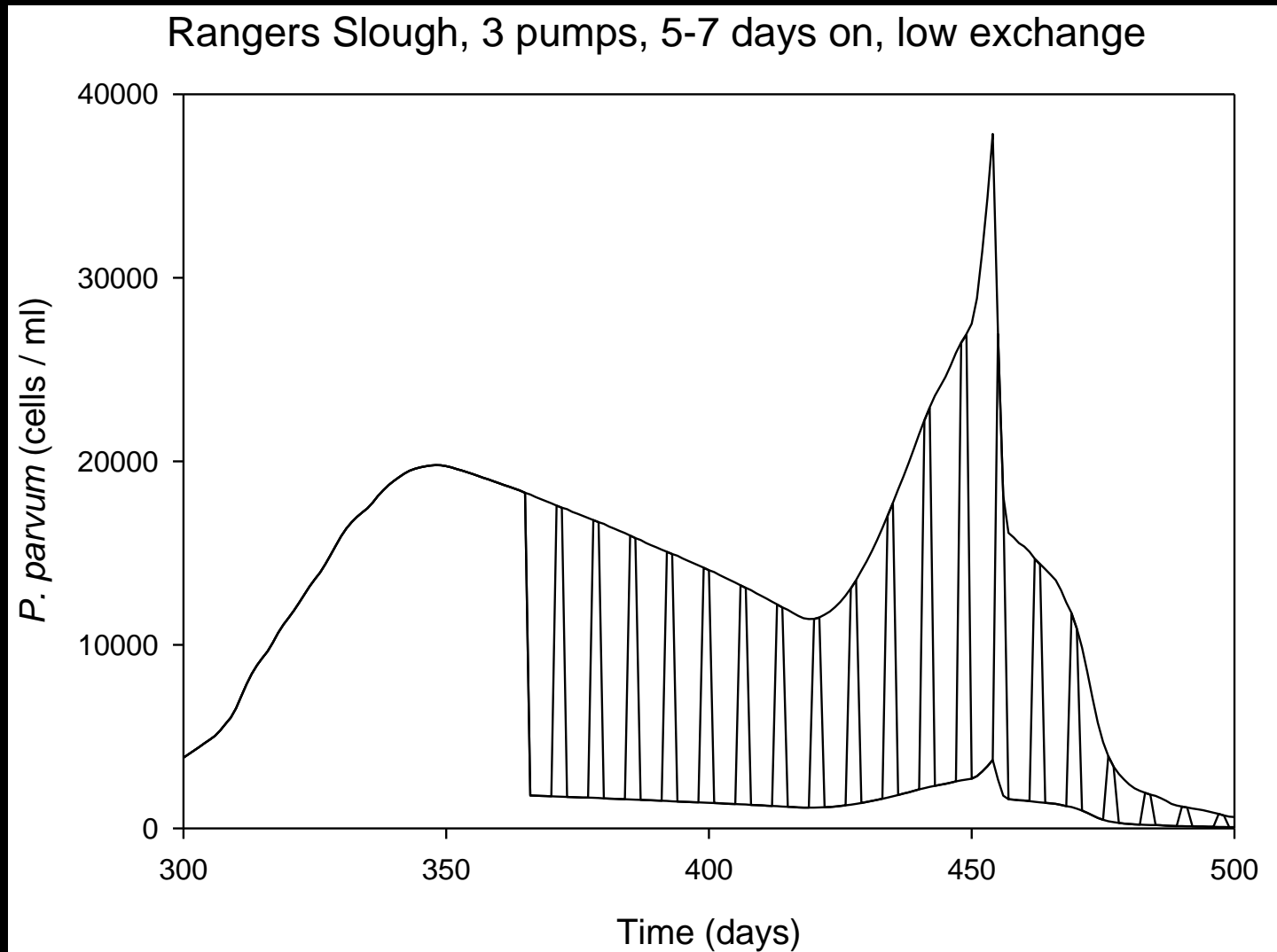
Biological model



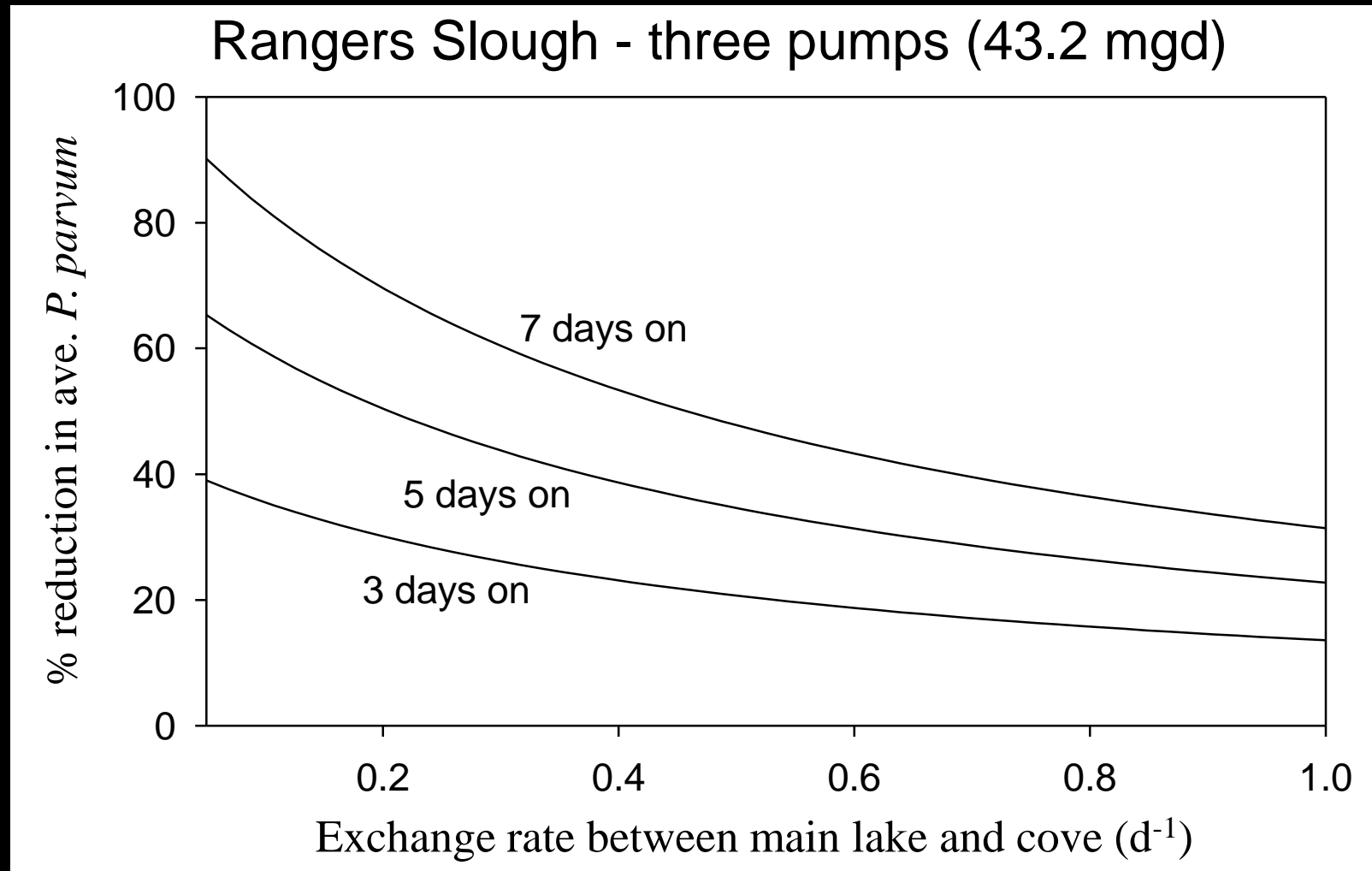
Coupled biological-physical model



Predicted dynamics with managed cove flushing



Estimated effects of managed cove flushing



Managed cove flushing - Lake Granbury

Summary

- Approach will reduce *P. parvum* in coves, not eliminate it
- Higher rates of managed flushing better
- More days of managed flushing better

Next steps

- A need for a demonstration project
- A need for financial support



What about cyanobacteria?



N-limited *Cylindrospermopsis* Producers
Toxin ($\mu\text{g} / \text{liter}$)

